A Strategic Case of Infusing Sustainability and Integrative Education in a Korean High School Pre-Engineering Course

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Abstract – Sustainable development brings many potential benefits to our society and the environment. Therefore, on both the global and national level, many educational communities have taken efforts to accept and implement the concepts of sustainability in K-12 classrooms. Recently the Korean government announced an educational policy emphasizing integrative efforts among STEM (Science, Technology, Engineering, and Mathematics) subjects. This study was started with the intent to deliver contents related to sustainability concepts and integrating their STEM contents into the K-12 classroom. This study investigated a case of infusing sustainability and integrative education in a high school classroom. In this case, systematic course development was conducted in three steps: preparation, development, and improvement. In addition, this study implemented sustainability through the systematic course development process. One semester pre-engineering course for 10th grade students was developed and delivered to 127 high school students in four classrooms. A self-reporting instrument was administered to the participants regarding their academic motivation toward science and technology school subjects and their attitude toward engineering. Data collected from the instruments and interviews were analyzed qualitatively and quantitatively. The research findings included: 1) High school students' learning motivation toward science and technology subjects was significantly improved through this pre-engineering course and 2) Their attitudes toward engineering were significantly improved through this pre-engineering course. These findings provide sound evidence supporting integrated sustainability concepts delivered through the STEM framework into K-12 educational settings.

Keywords: Pre-engineering, K-12 Engineering, Technology Education, Science Education, Course Development.

INTRODUCTION

Sustainability has gained popular momentum to enable all people to meet their basic needs and improve their quality of lives, while ensuring the natural systems, resources and diversity upon which they depend are maintained and enhanced for both their own benefit and that of future generations [1]. Also, sustainability has been recognized in our society as beneficial. For example, sustainable design has been implemented in many construction, engineering and technology areas to reduce the impact of environmental issues such as water and air pollution, resource depletion and to achieve social and economic benefits. K-12 education also has offered specific programs and courses emphasizing sustainability to educate future civilian. The key goals of this sustainable education have been to educate students to advance sustainability knowledge and practices and to change their attitude and behavior toward sustainability [2, 3]. In addition, education is also stated to be an indispensable means of "achieving environmental and ethical awareness, values, and attitude, skills and behavior consistent with sustainability and for effective public participation in decision-making" [3]. Federico and Cloud indicated that K-12 education is a major influence on the truth, attitudes, ethics, concepts, and behaviors of American society so that it is necessary to reshape K-12 education in the USA. to systematically and effectively foster sustainability. Since the education of

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teaching sustainability in K-12 is vital, educators should develop an instructional module to teach the concept of sustainability and its practices that can make great progress toward the achievement of a sustainable world.

In addition to the sustainability, STEM (Science, Technology, Engineering, and Mathematics) education has been one of the predominant issues in K-12 education. Great concern toward STEM education has arisen in the USA, and this trend has also been pervasive to many developed countries. In other words, global educational communities are enjoying realizing the benefits of integrative STEM education and looking for exemplary cases of implementation of STEM education in K-12 settings. Integrative STEM education emphasizes instructional efforts associated with the teaching and learning of STEM contents and processes under the context of technological/engineering design methods in this study.

The purpose of this study was to develop an integrative and sustainable pre-engineering program designed for high school students and investigate students' attitudinal transitions (students' motivation toward STEM subjects and students' attitude toward Engineering) through the semester pre-engineering program. This study adopted a systematic course development theory and a case study which may be used as an example for implementing the developed course in a high school setting.

BACKGROUND

Education for Sustainable Development

The concept of sustainability (including sustainable development) can be defined with different perspectives in various areas. This study was started with the most widely accepted definition toward sustainability where sustainable development "meets needs of the present without compromising the ability of future generation to meet their own needs" (WCED: World Commission on Environment & Development) [4]. Based on this definition, prior studies have developed diverse instructional programs infusing the concept of sustainability. Also, STEM educators and their professional communities have emphasized the need and value of delivering the sustainability concept into their classrooms [5, 6]. As a dominant learning topic, energy related programs have been spotlighted by STEM educators. In particular, this study employed the theme of sustainable energy and developed a semester length pre-engineering program.

Technology and Engineering Education in South Korea

Global efforts to include technology and engineering education into general education have resulted in significant curriculum innovations in recent years. The rapid technological innovations and economic impacts have led to the rationale to include technology subject in the Korean national curriculum since 1970. Technology education has been implemented under the Korean national curriculum framework. Recently, the Korean government has announced a STEAM (Science, Technology, Engineering, Arts, and Mathematics) education policy for boosting students' motivation and career awareness toward STEM fields [7]. In this environment, Korean technology teachers have developed diverse pre-engineering courses for high school students and implemented them in an integrative strategy. They have actively employed the STEAM education in their classrooms. High school technology education in the Korean national curriculum contained two large learning units: Energy and Transportation Technology and Construction Technology in 2011 [8]. This study developed a semester length class for teaching the two learning contents and concentrated on these two key concepts of the sustainable development and integrative strategies among STEM areas.

Students' Impact through Integrative STEM Education

The integrated curriculum has been proposed as an effective way to improve students' performance and one of the factors affecting performance improvement is students' motivation. The integrative instruction among STEM subjects can positively improve students' motivation toward STEM school subjects and STEM career fields [9, 10]. Kwon & Lee performed prior studies investigating the motivational benefits and concluded that there was a clear benefit by adopting integrative STEM education [9]. In particular, previous studies have indicated several benefits of integrating STEM subjects such as students' cognitive improvement (academic achievements in STEM related subjects), their affective development (attitudinal development toward STEM subjects), and enrollment in the STEM subjects and/or areas. This study was designed to investigate high school students' impacts on their motivation toward STEM subjects and attitude toward engineering through the integrative STEM education.

RESEARCH DESIGN

This study followed three stages, preparation, development, and improvement, to accomplish the research goals. The research framework is presented in Figure 1. During the preparation stage, the authors of this study reviewed prior studies that investigated sustainable development and integrative education. Also, data concerning diverse high school pre-engineering programs developed by exemplary Korean technology in-service teachers were collected and analyzed by the research group. The findings indicated insufficient implementation on the integrative approach and sustainable development. In particular, prior studies pointed out the low students' motivation toward STEM learning due to the difficulty of the material. Another issue found in the literature review was failure to cover the national curriculum guidelines. Two learning units (construction technology and transportation technology) for 10^{th} grade technology education should be covered within one semester.

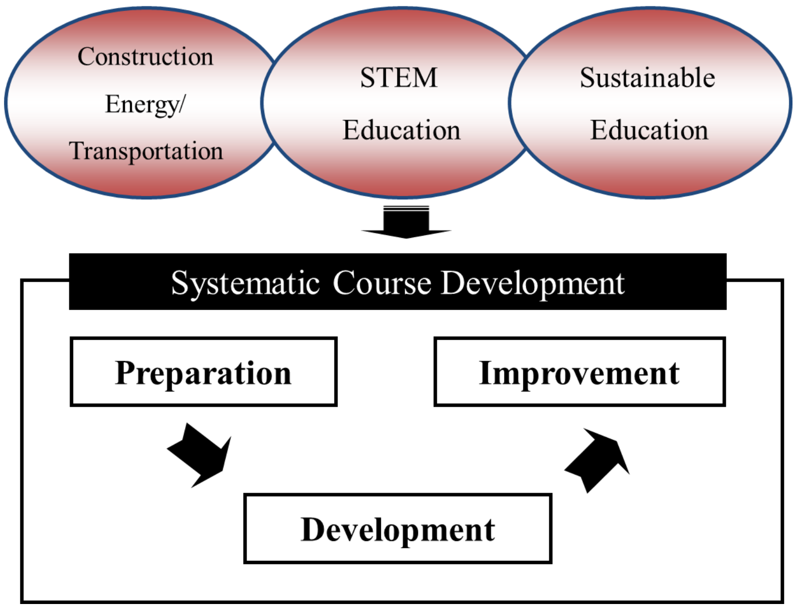

Figure 1. A Research Framework for Systematic Course Development

Course Development

The development stage consists of creating the framework for the pre-engineering program by choosing the goals and objectives for the program, the learning content, instructional strategies, and the assessment plan. The developmental procedure follows Wiggin and McTighe' backward design with three components, "identifying desired results-determine acceptable evidence-plan learning experiences and instruction." In addition, the outline is presented in Figure 2.

During the development stage, a semester length course including the sustainable development and integrative STEM approach was developed for 10^{th} grade students. The program developed in this study was designed for improving students' motivation and career awareness by using two student projects infusing the concepts of the integrative strategy between STEM and sustainable development. These two projects: (1) created a sustainable building model (for construction technology); and (2) constructed a solar-wind car model (for transportation technology). Each project had strong integrative learning components. The concrete conceptual map of the first project is presented in Figure 3 as an example. All the learning contents were based on the Korean national curriculum for Science, Technology, and Mathematics. Also, the projects were performed in the context of design based learning and teamwork. The final outcomes from this stage were students' worksheets and teachers' guidelines for each instructional module.

Goals Desired Results	Increasing Students' Motivation toward STEM - Students' Motivation for STEM - Students' Attitude toward Engineering Facilitating Students' Projects - Sustainable Development - Integrative STEM Education
Contents Energy!! Sustainability	Creating a Sustainable Building Model - Earth Science, etc - Geometry, Data Analysis, etc - Construction Technology Constructing a Solar-Wind Car Model - Physics, Earth Science, etc - Transportation Technology, etc
Instruction Strategies	Design(Project) Based Learning Integrative Project (STEM + Other Areas) Team/Collaborative Work Assessment Planning

Figure 2. A Systematic Approach for Course Development

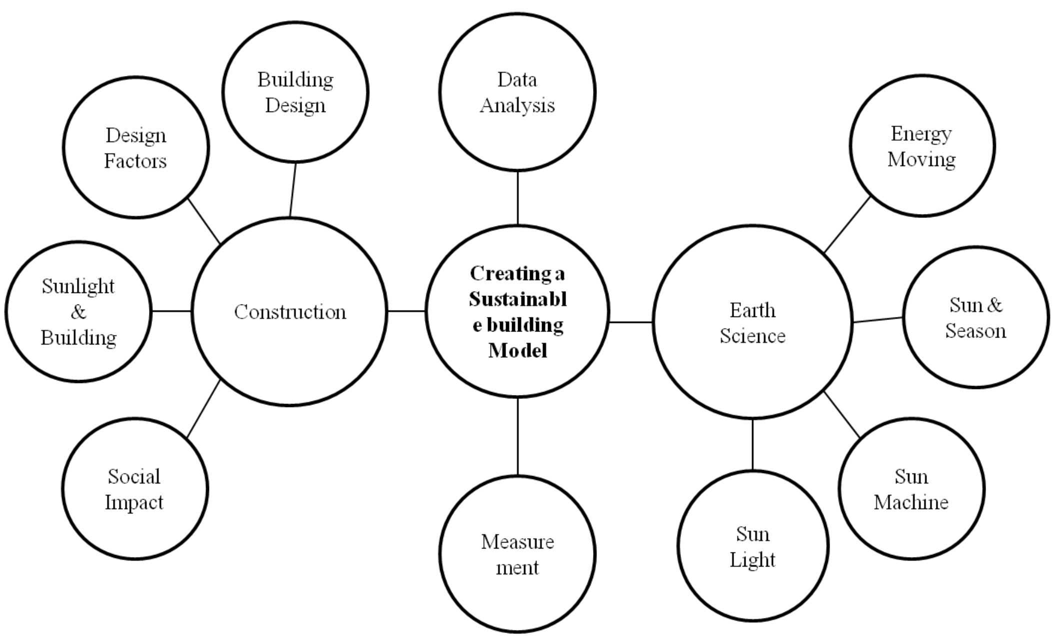

Figure 3. A Conceptual Map for "Creating a Sustainable Building Model"

Improvement Stage

The improvement stage consisted of evaluating the developed program, improving the program, and implementing the final program. The evaluation was performed by an expert group who consisted of three in-service teachers and two educational researchers. They reviewed the program outline, students' worksheets, and teachers' guidelines. All the feedback from the evaluation process was considered for improving the developed program. The final program was implemented in two high school technology education classrooms for a semester in 2011.

The participants of this study were 127 high school students in a 10th grade technology education class. They were all male students who were required to complete this technology education program as a requirement. To investigate students' attitudinal transitions regarding their motivation and career awareness toward STEM, this study employed a pre-test and post-test strategy using a valid and reliable instrument validated previously. Also, data from students' work, portfolio, and interviews were collected for supporting the quantitative data.

The instrument in this study had four sections: (1) Background information (student identification number, informed consent form, and future career), (2) Self-efficacy for STEM subjects, (3) Assessment anxiety for STEM subjects, and (4) Attitude toward engineering. The motivational instrument for STEM subjects was measured by a modified version of Science Motivation Questionnaire (SMQ) originally developed by Glynn and Koballa [11]. The SMQ originally measured six different constructs such as intrinsic motivation, extrinsic motivation, personal connection, self-determination, self-efficacy, and assessment anxiety in students' science learning. This study adopted self-efficacy and assessment anxiety and modified it into two sections of the Science Learning Motivation (SLM) and Technology Learning Motivation (TLM). The last measurement in this study also employed a part of the Pupils' Attitude Towards Technology (PATT) to measure students' attitude toward engineering. The PATT was a valid and reliable instrument originally developed by Ratt and de Vries to measure students' attitude toward technology [12]. It was modified by Moon to investigate elementary school students' attitude toward engineering. This study adopted it for measuring high school students' attitude toward engineering such as interest toward engineering, perceived importance of engineering, perceived creativity of engineering, and perception toward engineering career.

A pre-test and post-test strategy of the instrument was performed in two high school classrooms. The collected data were analyzed by a paired sample *t*-test to investigate students' attitudinal transition using SPSS 20.

FINDINGS

An Integrated Pre-engineering Course

An integrated pre-engineering program was designed by the research team (two high school technology teachers and two technology education researchers) as a mandatory class for high school 10th graders. Also, this developmental study followed six stages as shown in Figure 4. In the first stage, this study reviewed the technology education curriculum (transportation technology and construction technology) for high school students and chose all the contents related to the sustainable development.

A goal statement for this course was created and specific objectives were developed. The goal was to develop students' understanding, attitude, and competency toward sustainable development in technology and engineering project. The specific objectives were described as follows: (1) Understanding sustainability concepts, transportation technology, and construction technology, (2) Developing students' attitude toward sustainable development, STEM areas, social impacts of the technology and engineering work, and integrative teamwork project, and (3) Developing students' ability of problem solving through an integrative strategy.

Five learning sections were selected for meeting the goal and objectives. The first section was to introduce STEM based learning strategy to high school students and included a lecture and several discussion sessions regarding the definition, benefits, and exemplary cases of the integrative STEM projects. Other sections delivered two types of instructional strategies: a short lecture and an integrative hands-on project.

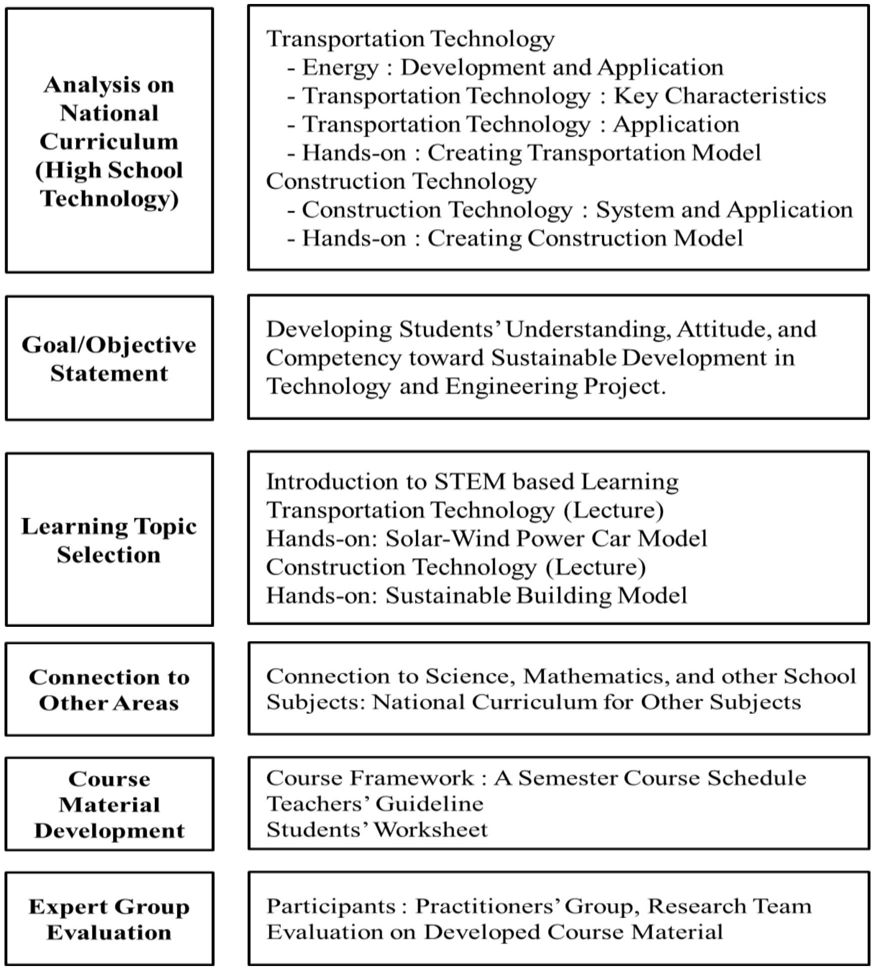

Figure 4. Developmental Process for an Integrated Pre-engineering Course

Connecting the organized learning content to other school subjects was required to develop an integrative STEM program. Based on the national curriculum for other subjects, the research team met to choose learning content from other subjects. Finally this study developed three course materials: (1) Course framework, (2) Teachers' guideline, and (3) Students' worksheet. The developed framework for a semester pre-engineering course is presented in Figure 5.

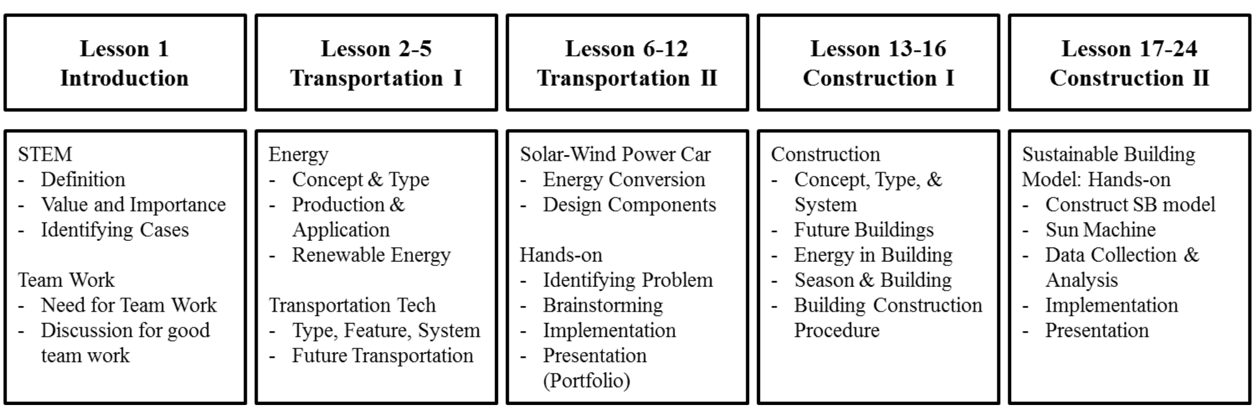

Figure 5. Course Framework for an Integrated Pre-engineering Course

Students' Self-efficacy

Students' self-efficacy was analyzed by the paired samples *t*-test. Self-efficacy toward science learning and self-efficacy toward technology learning were analyzed respectively (See Table 1 & Table 2). In students' self-efficacy toward science learning, there was no significant difference between pre-test and post-test. However, students' self-efficacy toward technology learning was significantly improved through this pre-engineering course (t=-3.084, p<0.05).

Table 1. Descriptive Data for Self-efficacy

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test (Self-efficacy toward Science)	3.0332	127	.60427	.05362
	Post-test (Self-efficacy toward Science)	3.1172	127	.60199	.05342
Pair 2	Pre-test (Self-efficacy toward Technology)	3.1575	127	.51233	.04546
	Post-test (Self-efficacy toward Technology)	3.3263	127	.62600	.05555

Table 2. The Paired Samples *t*-test Results for Self-efficacy

	Paired Differences			*t*	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean			
Pre-test – Post-test (Self-efficacy toward Science)	-.08399	.52820	.04687	-1.792	126	.076
Pre-test – Post-test (Self-efficacy toward Technology)	-.16885	.61703	.05475	-3.084	126	.003

Students' Attitude toward Engineering

Students' attitude toward engineering was analyzed by the paired samples *t*-test. Students' interest, perceived importance, perceived creativity, and career motivation toward engineering were analyzed respectively (See the Table 3 & Table 4). For students' career motivation, there was no significant difference between pre-test and post-test. However, students' interests, perceived importance, and perceived creativity toward engineering were increased respectively over this course (t=-4.556, p<0.05; t=-5.025, p<0.05; t=-5.366, p<0.05).

Table 3. Descriptive Data for Students' Attitude toward Engineering

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test (Interest)	3.0194	127	.80333	.07128
	Post-test (Interest)	3.3180	127	.74657	.06625
Pair 2	Pre-test (Importance)	3.2687	127	.65334	.05797
	Post-test (Importance)	3.5492	127	.52661	.04673
Pair 3	Pre-test (Creativity)	3.0394	127	.77165	.06847
	Post-test (Creativity)	3.3701	127	.63444	.05630
Pair 4	Pre-test (Career Motivation)	3.2402	127	.82820	.07349
	Post-test (Career Motivation)	3.2638	127	.95083	.08437

Table 4. The Paired Samples *t*-test Results for Students' Attitude toward Engineering

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	Pre-test (Interest) Post-test (Interest)	-.29861	.73856	.06554	-4.556	126	.000
Pair 2	Pre-test (Importance) Post-test (Importance)	-.28051	.62910	.05582	-5.025	126	.000
Pair 3	Pre-test (Creativity) Post-test (Creativity)	-.33071	.69452	.06163	-5.366	126	.000
Pair 4	Pre-test (Career Motivation) Post-test (Career Motivation)	-.02362	.94881	.08419	-.281	126	.779

CONCLUSIONS

This study investigated a case of infusing sustainability concepts and integrative education in a high school technology subject. In this case, a systematic course development was conducted in three steps : preparation, development, and improvement. A semester length pre-engineering course for 10th grade students was developed and implemented for 127 high school students in two technology classrooms. Students' self-efficacy toward technology learning was significantly improved over this course while their self-efficacy toward science learning was not significantly improved. Students were not familiar with hands-on problem solving project approach used in science classrooms. In other words, hands-on based problem solving strategy as a key pedagogy has not been accepted for contemporary high school science education. Also, students' attitudes toward engineering were significantly improved over this course. The pre-engineering course infusing sustainability concepts and integrative efforts developed students' positive attitudes toward engineering. Specifically, the integrative class projects helped students have more interest toward engineering. Also, the pre-engineering course including sustainability concepts assisted them to consider sustainability components in their group project.

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